A Brief History of Computation (pre-1900)

15-112 (4/23/2019)

Learning goals

- Become familiar with the history of computing devices from ancient times to the 1800s
- Understand early driving forces of innovation in computation
- See some cool automata and appreciate mechanical computation

Discuss: What is computing? What is a computer? Try to come up with concrete requirements!

Let’s use a loose definition for today

- Loosely, something that generates an output given a particular set of inputs or initial configuration
- We’ll restrict ourselves to inputs and outputs that (mathematically) represent concepts or parts of problems
- Generally they solve (or allow us to solve) a set of problems faster
- A simple example: multiplication tables

Multiplication Square

X	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	4	6	8	10	12	14	16	18	20
3	3	6	9	12	15	18	21	24	27	30
4	4	8	12	16	20	24	28	32	36	40
5	5	10	15	20	25	30	35	40	45	50
6	6	12	18	24	30	36	42	48	54	60
7	7	14	21	28	35	42	49	56	63	70
8	8	16	24	32	40	48	56	64	72	80
9	9	18	27	36	45	54	63	72	81	90
10	10	20	30	40	50	60	70	80	90	100

Simple computers

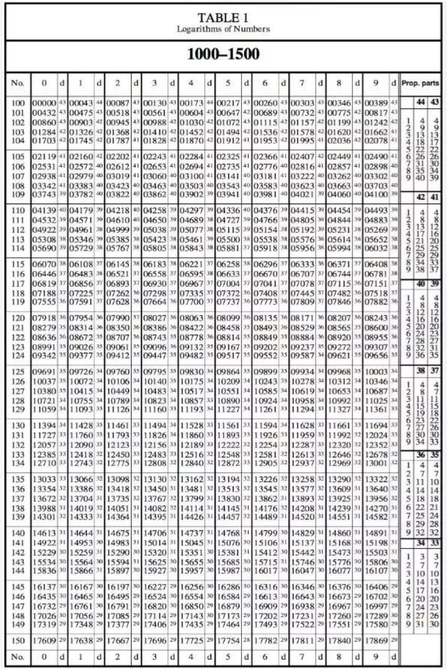
Function tables: How do they "work?"

It stores precomputed knowledge that we can systematically access to perform calculations faster.

To the right is an image of a rather intimidating logarithm table ---->

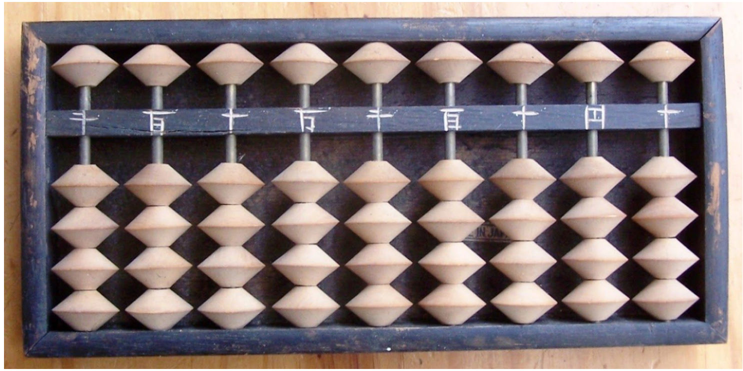
Multiplication Square

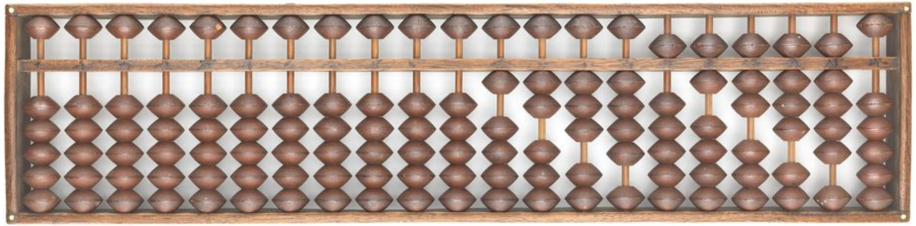
x	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	4	6	8	10	12	14	16	18	20
3	3	6	9	12	15	18	21	24	27	30
4	4	8	12	16	20	24	28	32	36	40
5	5	10	15	20	25	30	35	40	45	50
6	6	12	18	24	30	36	42	48	54	60
7	7	14	21	28	35	42	49	56	63	70
8	8	16	24	32	40	48	56	64	72	80
9	9	18	27	36	45	54	63	72	81	90
10	10	20	30	40	50	60	70	80	90	100



The abacus: 2500BC to present

- Originally lines drawn in sand, pebbles
- Oldest known “computer,” excluding simple counting aids like tally sticks
- Procedural interaction allows user to perform four-function math on large numbers by storing an intermediate state
- Still in widespread use until recent decades
  - Japanese soroban was taught nationally and used in business until recently
- http://www.mathematik.uni-marburg.de/~thormae/lectures/ti1/code/abacus/soroban.html





Napier's Bones (1617)

Physical aid for multiplying large numbers

Represented with pen and paper *or* with inscribed rods: http://mathworld.wolfram.com/NapiersBones.html

John Napier also invented logarithms!

Slide rules: 1620 - 1950

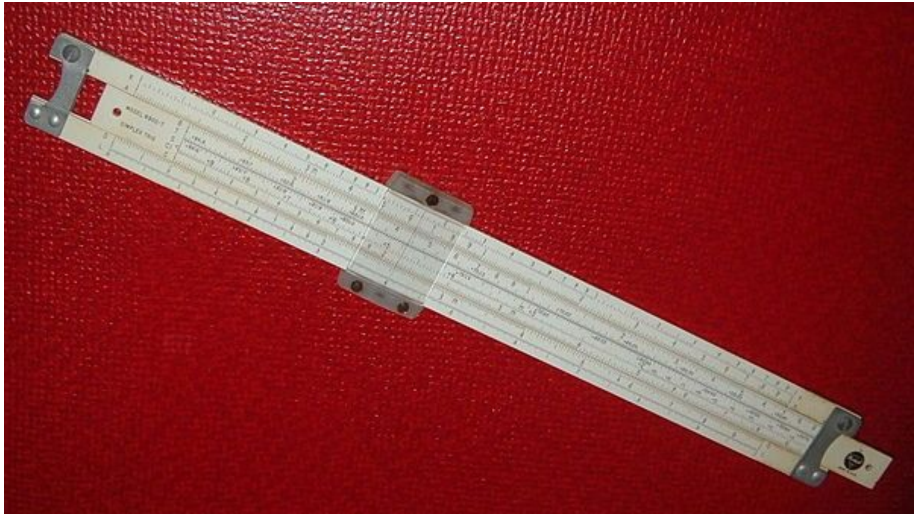
Basic principle:

$$\log(xy) = \log(x) + \log(y)$$

$$\log(x/y) = \log(x) - \log(y)$$

Multiplication and division can be quickly performed using the sum of logarithms!

https://en.wikipedia.org/wiki/Slide_rule



Mechanical calculators (1623 - 1970)

Similar function to previous tools, but meant to be more convenient or automatic

Antikythera mechanism

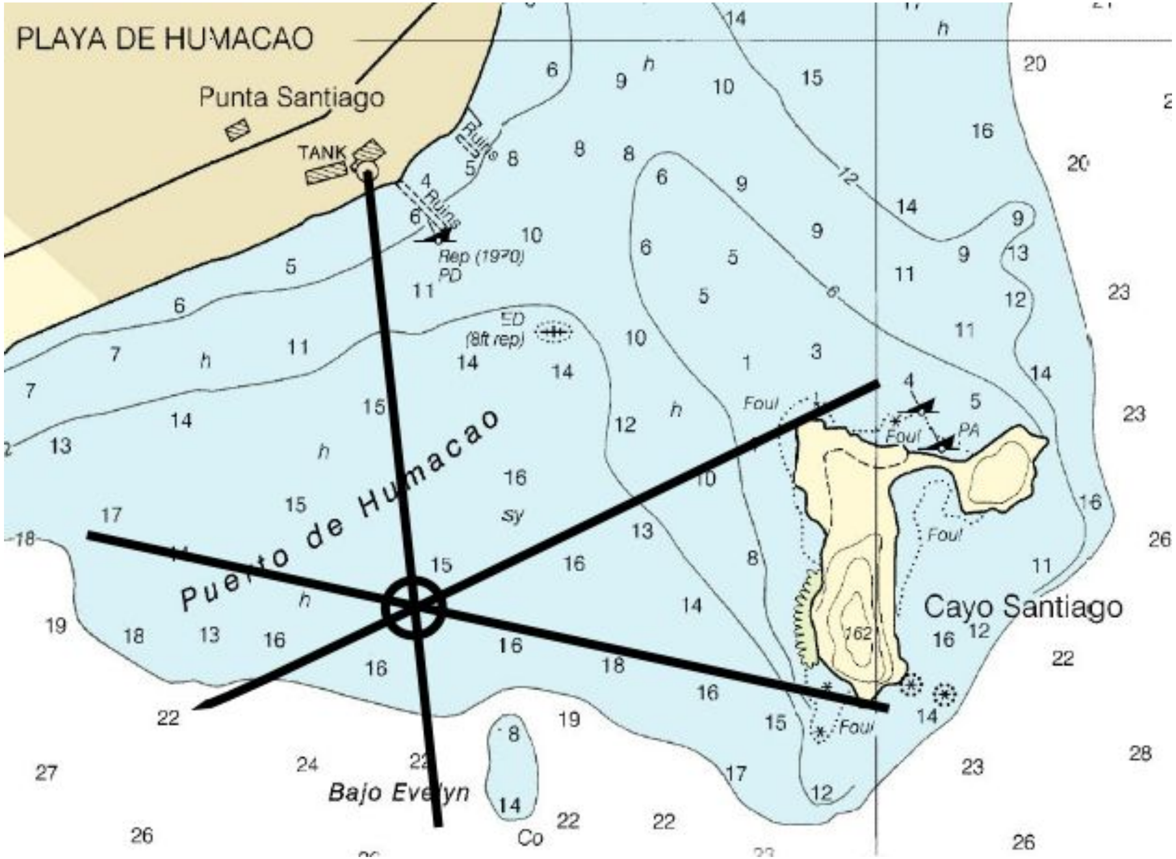
Mechanical complexity is *ancient*

- Antikythera mechanism: 2100 years old
- Accurately calculates celestial positions, eclipses, etc
- https://www.youtube.com/watch?v=UpLcnAIpVRA&feature=youtu.be&t=164
- Discuss: Why might this have been built?

Navigation!
A major incentive for innovation

Discuss the following questions

- If you can see three landmarks, how do you find where you are on a map?
- Without a compass, how can we (accurately) determine which way is north?
- If you can't see landmarks, how can you determine latitude (north/south position)?



Positional navigation using landmarks

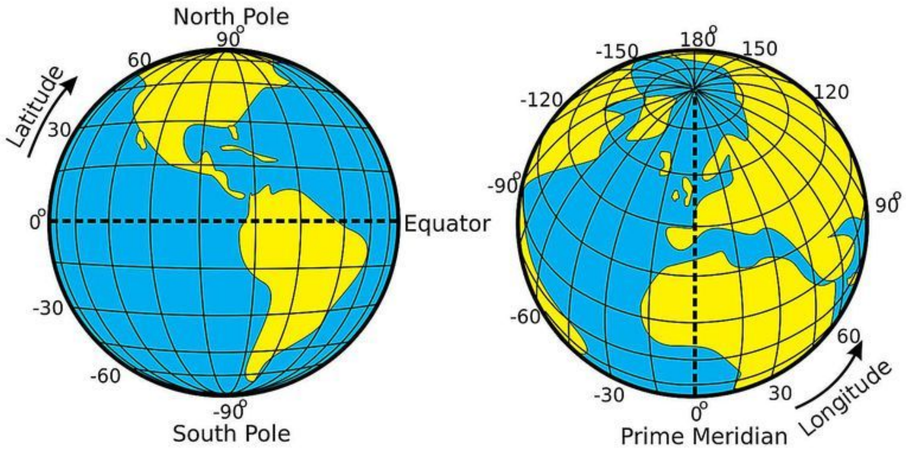
Sextants, astrolabes, etc for measuring angles

Discuss: Why is longitude harder to determine? What do we need to know first?

Time!
Can’t navigate across an ocean without knowing the time.

Why is time important for navigational calculations?

- When we travel long distances, the sky changes
- Small errors are a big deal over large voyages



- So let's build a clock! Why is this hard?
  - Mechanical
  - No way to correct fast/slow if clock if you're alone in the ocean (don't know where)
  - Clock must be *extremely* accurate and precise, even through rough weather

Quick aside: How long have battery-powered watches been widespread?

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...about 35 years. Before the 1980s, most watches were entirely mechanical.

The first “electric” watches from 1969 were absurdly expensive and still relied on mechanical regulation of time.

The first all-digital watch cost more than $2k when it first came out in 1970.

Discuss: What functional parts do we need for a mechanical timekeeper?

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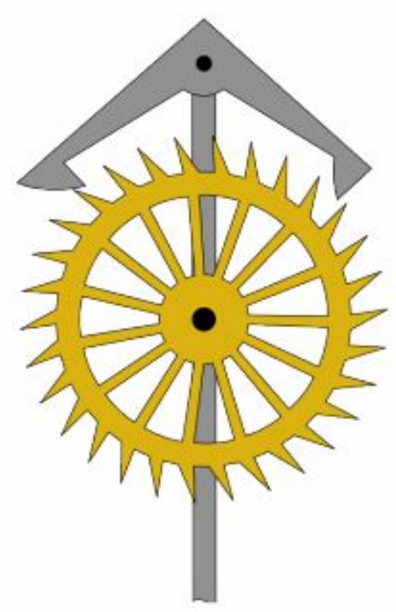
1. A way to store energy (a spring)

2. A way to convert between seconds, minutes, and hours (gears)

3. Most importantly: A way to move the hands at a very constant rate. **Ideate: How would you do that?**

The Escapement

- Why watches and clocks “tick”
- https://en.wikipedia.org/wiki/Escapement
- The escapement keeps the spring from rapidly unwinding
- A pendulum (or escape wheel, i.e. a rotary pendulum) allows the gears to advance a fixed amount at every oscillation
- The escapement also injects energy to keep the pendulum moving



Explanatory video:
https://youtu.be/rL0_vOw6eCc?t=370

Back to navigation

- Early timepieces were still inaccurate
- Isochronism: The ability to keep time at a constant rate over long periods of time
- 1714: British government offers the Longitude Prize, $4 million in 2019 currency for the first clock accurate enough for navigation
  - John Harrison wins the prize in 1761 after 31 years of dedicated work to improve the escapement
  - Chronometer escapement: https://www.youtube.com/watch?v=cQvopnjDI6E

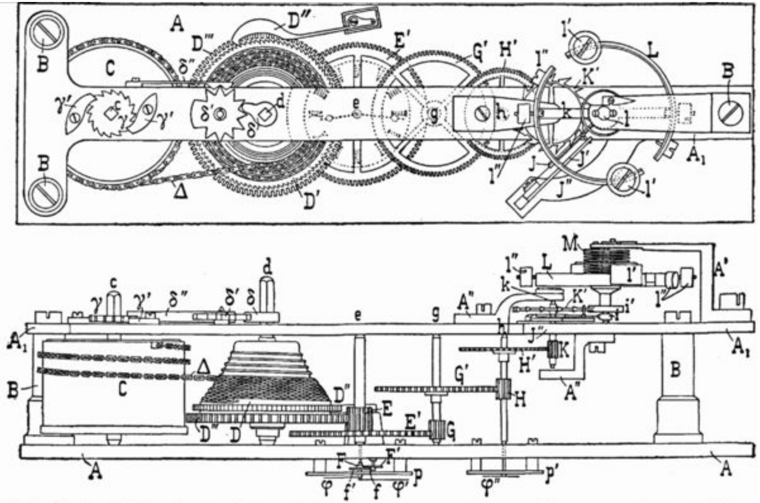


Fig. 1. *A* obere Platine. A_1 untere Platine. *A′* Brücke der Unruhe. *A″* Brücke der Hemmung. *B* Pfeiler der Platine. *C* Federhaus. *c* Federwelle. *γ* Sperrad für die Feder. *γ′* Sperrkegel. *D* Schnecke. *D′* Gegenſperrad. *D″* Sperrfeder für das Gegenſperrad. *D‴* Schneckenrad. *d* Schneckenwelle. *Δ* Kette. *δ* Zahn der Stellung. *δ′* Stellungsrad. *δ″* Stellungsfeder. *E* Trieb des Großbodenrads. *E′* Großbodenrad. *e* Achſe des Großbodenrads. *F* Minutenrohr. *F′* Wechſelrad. *f* Trieb des Wechſelrads. *f′* Stundenrad. *φ* Stundenzeiger. *φ′* Minutenzeiger. *φ″* Sekundenzeiger. *G* Trieb des Kleinbodenrads. *G′* Kleinbodenrad. *g* Achſe des Kleinbodenrads. *H* Trieb des Sekundenrads. *H′* Sekundenrad. *h* Achſe des Sekundenrads. *J* Hemmungsfeder. *J′* Anſchlagkloben für die Hemmungsfeder. *J″* Brücke der Hemmungsfeder. *i* Kleine Rolle. *i′* Große Rolle. *K* Trieb des Hemmungsrads. *K′* Hemmungsrad. *k* Steg der Unruhe. *L* Unruhe. *l* Achſe der Unruhe. *l′* Kompenſationsgewichte. *l″* Regulierſchrauben. *M* Spirale.

From watches to automata: Machines with programs

Birdcage demonstration

This machine executes a mechanical program!

Automata became popular in the 1700s, though there are ancient examples as well

Other (more impressive) automata

Brittany Nicole Cox and Antiquarian Horology: https://www.youtube.com/watch?v=irdTng8MbIE

Late 1700s Creepy music robot: https://www.youtube.com/watch?v=nITEU4fsqCU

Late 1700s Writing robot: https://www.youtube.com/watch?v=C7oSFNKIIaM

Which automaton or device did you find most interesting so far?

Submit your answer (and your attendance) to: http://bit.ly/112attend-gears

Programmable computing

Jacquard loom

Complex textile patterns achieved using a series of punch cards

https://www.youtube.com/watch?v=MQzpLLhN0fY

Charles Babbage

Difference engine:

- Tabulated values for polynomial functions, potentially saving lots of manual labor
- https://www.youtube.com/watch?v=XSkGY6LchJs

Analytical engine: General-purpose computer

- Capable of arithmetic, conditionals, and looping
- Fully designed but never built

Ada Lovelace

Published first algorithms designed specifically for a computer (the analytical engine)

Wrote extensively about the applications of computers beyond the purely mathematical

[The Analytical Engine] might act upon other things besides *number*, were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations, and which should be also susceptible of adaptations to the action of the operating notation and mechanism of the engine

This brings is to the 1900s, where...

- More mechanical (and then electro-mechanical computers) were built
- WWII saw the practical use of computers and computational theory in cryptography
- Computers became ever more general-purpose
- Limits of computation and other theoretical research took off
- Innovations in miniaturization and electronics (i.e. transistors) propelled us into our current age of small, inexpensive computing and vastly powerful supercomputers

That’s it for today!
If you’re interested in this topic, look at the website for History of Computing 15-292 and consider taking it next time it’s offered!